SME–University Collaboration in Non-metropolitan regions

A Multiple Case Study Analysis of How Collaborations Start and Unfold

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Abstract

The industry-university collaboration literature has studied the factors that are positively related to industry-university collaboration; however, not much is known about the relevance of these factors in different types of regions. Similarly, not much is known about the factors that are related to the initiation of collaboration with universities; and its unfolding. In order to help fill these gaps in the literature, the present study discusses the results of a multiple case study aimed at uncovering factors associated with the initiation and unfolding of industry-university collaboration among 7 SMEs operating in non-metropolitan regions of Denmark, Norway and Portugal. In order to highlight factors specific to the non-metropolitan SMEs, the case study also includes 4 cases of SMEs in metropolitan regions of the same countries. Among the non-metropolitan cases, the local universities play an active role in starting relations with the focal SMEs. These relations later on evolve, incentivised by the goal of satisfying international customers and supported by public funds, from non-collaborative relations such as student internships into collaborative research. Having an R&D department helps the non-metropolitan SMEs integrate university knowledge, and these firms developed their R&D departments while building on their collaboration with the focal university. The findings from the case studies contribute to the industry-university collaboration literature, by pointing out at factors associated with the initiation, and unfolding of industry-university collaboration among firms in non-metropolitan regions.

Keywords: start of industry-university collaboration; unfolding of industry-university collaboration; non-metropolitan universities; non-metropolitan regions; metropolitan regions

JEL: O31, O32, R10, R11, R12

1. Introduction

Over the last decades, governments have been developing policies to stimulate firm–university collaboration with the goal of promoting firm innovation and reducing regional economic disparities (Charles, 2006). In non-metropolitan regions, such policies are enacted in an environment where there is typically one main university campus or a few branch campuses (Boucher et al., 2003; Charles, 2016; Eder, 2019; Trippl et al., 2018). Moreover, industry–university relations in non-metropolitan regions are influenced by a thin labour market for university graduates, with a relatively small proportion of university graduates in the regional labour force (Ahlin et al., 2014; Evers, 2019; Faggian and Mccann, 2009) or a relatively high proportion of firms from sectors that have not traditionally relied on university knowledge (Jauhiainen and Moilanen, 2012; Tödtling and Trippl, 2005, 2015). Thus, to a certain extent, non-metropolitan regions can be regarded as an economic periphery in relation to metropolitan centres (Eder, 2019). However, local universities in non-metropolitan regions have also played a key role as regionally engaged innovation partners providing regional firms with otherwise not readily available research capabilities (Alpaydin et al., 2018; Boucher et al., 2003; Fonseca and Çinar, 2017; Guerrero and Evers, 2018[1]).

Most of the literature on the drivers of industry–university collaboration has not addressed explicitly how factors associated with industry–university collaboration might relate to firm–university collaboration in different types of regions (D'Este et al., 2013; D'Este and Iammarino, 2010; Hewitt-Dundas et al., 2019). Nevertheless,

[1] Paper 1 in the thesis.

Guerrero (2020a)[2] and Guerrero (2020b)[3] observed that firms in non-metropolitan regions of Denmark that have a main university campus are more likely than firms in the Copenhagen metropolitan region to collaborate with universities, whereas firms in non-metropolitan regions without a main university campus are as likely as their metropolitan counterparts to collaborate with universities.

However, little is known about the factors that influence collaborations between firms in non-metropolitan regions and universities. Most of the firms in non-metropolitan regions are small and medium-sized enterprises (SMEs) (Tödtling and Trippl, 2005, 2015), and SMEs are less likely than larger firms to collaborate with universities (Laursen and Salter, 2004; Segarra-Blasco and Arauzo-Carod, 2008). Compared to metropolitan regions, firms in sectors that have not traditionally relied on university knowledge dominate non-metropolitan regions (Jauhiainen and Moilanen, 2012; Tödtling and Trippl, 2005, 2015).

The present multiple case study was aimed at contributing to the industry–university collaboration literature by exploring which factors are positively associated with industry–university collaboration on innovation in non-metropolitan regions. Further, the study explored which factors are positively associated with the initiation of industry–university collaborations in non-metropolitan regions and which factors are positively associated with the unfolding of these collaborations. Thus, the study explored the following question:

Which factors are associated with the initiation and unfolding of industry–university collaboration on innovation in non-metropolitan regions?

[2] Paper 2 in the thesis.
[3] Paper 3 in the thesis.

The literature has identified a group of factors which are positively associated with industry–university collaboration. A multiple case study approach would allow for exploring whether these factors are positively associated with the initiation of collaborations between the case firms and universities or the unfolding of these collaborations. The multiple case study design would also allow for exploring the ways in which these factors might be positively associated with industry–university collaboration at each stage of the industry–university collaboration process.

The main findings of the study are as follows: (i) Local universities play a key role in initiating what will become industry–university collaborations, with university researchers approaching the case firm or the firm being invited to events aimed at promoting industry–university links. Universities' initial attempts to approach the case firms can be supported by the information that interns provide to university professors regarding the firms' research capabilities. (ii) The goal of developing products that are attractive to international customers incentivises the case firms to develop their relationships with universities from non-collaborative links (e.g. hosting employees, commissioned research) to full-fledged collaborative research – that is, relationships where both parties engage in research and development (R&D) work. (iii) Public funding schemes support the transition to collaborative research, providing resources for making investments in organisational resources that firms must commit. (iv) Having an R&D department helps the case firms integrate university knowledge, and each case firm developed its R&D department while building on its collaboration with the focal university. These commonalities stand among non-metropolitan case firms even if they differ in aspects such as the firm's activity sector, the exact format of the collaborative research in which the

focal firm and university are currently involved and the types of public funding schemes that support such collaborative research.

The paper is structured as follows. The next section presents the literature review and the third section outlines the research methods. Next, the empirical context is discussed. The fifth section presents the empirical analysis. Afterwards, the findings are discussed. The final section concludes.

2. Factors related to industry–university collaboration in non-metropolitan regions

2.1. Characteristics of non-metropolitan regions and their potential implications for industry–university collaboration

Non-metropolitan regions are locations beyond the commuting reach of a metropolitan agglomeration, which can include areas with at least one urban agglomeration containing a main university campus. By contrast, metropolitan regions are home to larger urban agglomerations and multiple universities (Eder, 2019; Tödtling and Trippl, 2015; Trippl et al., 2018).

Non-metropolitan regions also tend to be home to a relatively small number of large firms, and firms in sectors that have not traditionally relied on universities to source knowledge are common. For instance, non-metropolitan regions might contain a relatively high proportion of SMEs such as machinery suppliers or fabricators of metal products (Pedersen, 2005; Teles et al., 2014; Tödtling and Trippl, 2005, 2015). Compared to firms that rely on university research as a usual component of their innovation strategies, firms in sectors that have not traditionally relied on universities are relatively unlikely to rely on R&D departments as part of their innovation strategies (Pavitt, 1984). Accordingly, having an R&D department has been found to be a predictor of industry–university collaboration (Laursen and Salter, 2004).

Moreover, non-metropolitan regions are organisationally thinner locations relative to metropolitan regions. In other words, compared to metropolitan regions, non-metropolitan regions have a smaller number and variety of knowledge-generating organisations, such as universities, research institutes and firms in different sectors (Trippl et al., 2015; Zukauskaite et al., 2017).

2.2. Factors associated with industry–university collaboration

This section discusses a set of factors that the literature has identified as being associated with industry–university collaboration. These factors are the role of non-metropolitan universities as facilitators of industry–university collaboration, the role of university graduates in industry-university relations, firms' access to governmental support schemes and firms' relations with organisations other than universities. The literature review is intended to support the exploration of whether and how these factors are associated with the initiation of industry–university collaboration processes and their unfolding.

2.2.1. The role of non-metropolitan universities in facilitating industry–university collaboration

From the discussion in section 2.1., it might seem that non-metropolitan regions are a relatively unfavourable terrain for industry–university collaboration to take root; however, quantitative evidence suggests otherwise. In Norway, firms in non-metropolitan regions are more likely than their metropolitan counterparts to collaborate with universities (Jakobsen and Lorentzen, 2015). Evidence from Guerrero (2020a) and Guerrero (2020b) suggests that in Denmark, firms in non-metropolitan regions where there is a main university campus are more likely to collaborate with universities than firms in the Copenhagen metropolitan region, whereas firms in non-metropolitan regions without a main university campus are as likely as their metropolitan counterparts to collaborate with universities.

Universities in non-metropolitan regions can be a key regional source of knowledge that is otherwise scarcely available to local firms in the region (Boucher et al., 2003). Universities in non-metropolitan regions that are actively involved in regional development engage in this work through a broad range of actions

connected to their third mission, such as training of graduates suited to the regional labour market, entrepreneurship training and spin-off formation, commissioned research services and collaborative research (Alpaydin et al., 2018; Charles, 2016; Evers, 2019; Fonseca and Çinar, 2017; Guerrero and Evers, 2018; Nilsson, 2006). The activities of these higher education institutions can be seen from the perspective of the entrepreneurial university concept, including different forms of technology transfer activities supporting innovation in local firms, such as contract research, consultancy, collaborative research or participation in cluster initiatives. These universities also tend to structure their educational mission in ways that support innovation in local firms by providing educational programmes and continuous training programmes suited to the firms' needs (Clark, 2004, 1998; Gjerding et al., 2006; Uyarra, 2010).

Yet not all universities in non-metropolitan regions are necessarily supporting innovation and development in the region's sectors. Universities might focus their efforts on strong, already established economic sectors in the region (Alpaydin et al., 2018), and in some non-metropolitan regions, the main economic actors, such as firm associations, might not be interested in establishing links with universities (Boucher et al., 2003). Despite these exceptions, the above discussion suggests that universities in non-metropolitan regions can play a key role in industry–university collaboration by performing actions that facilitate the initiation and unfolding of these collaborations.

2.2.2. Graduates' role in connecting firms and universities

The non-metropolitan universities in the study were founded in the 1970s and 1990s (see section 3.5.), and the rationale for establishing these institutions was related to providing university degrees in regions with limited access to this type

of education, which enabled an increase in the capacity of regional firms to absorb new knowledge, innovate and interact with universities (Evers, 2019; Faggian and Mccann, 2009; Guerrero and Evers, 2018). However, while educational levels in these regions have increased in the last decades, a relatively small proportion of the local workforce holds a university degree as compared to metropolitan regions (Evers, 2019; Faggian and Mccann, 2009; Guerrero and Evers, 2018; see table 2 in section 4.2.). This is so, in part, because non-metropolitan regions' thin labour markets offer a relatively poor fit between university graduates' qualifications and the jobs on offer. Consequently, a relatively large proportion of university graduates from non-metropolitan regions emigrate to the thicker labour markets of metropolitan regions, where they can find jobs that better fit their qualifications (Ahlin et al., 2014; Scott, 2010; Storper and Scott, 2009).

According to the literature, firms that employ university graduates are more likely to collaborate with university graduates because these graduates provide those firms with the capacity to acquire and assimilate university knowledge (Drejer and Østergaard, 2017; Laursen and Salter, 2004). The scarcity of university graduates in non-metropolitan regions, relative to metropolitan regions, can pose a challenge to non-metropolitan firms' ability to collaborate with universities.

2.2.3. The relevance of governmental support schemes

Firms that benefit from governmental support schemes are more likely to collaborate with universities (Mohnen and Hoareau, 2003; Segarra-Blasco and Arauzo-Carod, 2008). In addition, SMEs might have too little financial slack to become involved in collaborative relationships with universities (Bruneel et al., 2016), and public funding can provide them with access to the financial resources they need to conduct collaborative research with universities. In non-metropolitan

regions, SMEs account for a relatively high proportion of firms (Tödtling and Trippl, 2005, 2015). Thus, governmental support schemes might be particularly relevant to incentivise the initiation and unfolding of industry–university collaboration among firms in non-metropolitan regions. Nevertheless, it is unclear how exactly these funding schemes might relate to the unfolding of industry–university collaboration. It might occur, for instance, that they are more relevant in attracting firms to the possibility of forging different types of (not necessarily collaborative) relationships with their home universities.

2.2.4. Relations with organisations other than universities

Guerrero (2020a, 2020b) considered that firms in non-metropolitan regions might source external knowledge that is useful for innovation by relying on collaboration channels with other organisations, which are often located outside of their region. As non-metropolitan regions are organisationally thinner than their metropolitan counterparts, firms in non-metropolitan locations might not have the partners they need locally to collaborate in their innovative activities. Consequently, firms in non-metropolitan regions might resort to extra-regional collaboration channels to access suitable collaboration partners (Drejer and Vinding, 2007; Fitjar and Rodríguez-Pose, 2011; Grillitsch and Nilsson, 2015; Jakobsen and Lorentzen, 2015). Given that firms are more likely to collaborate with universities if they are sourcing knowledge from other sources as well (Laursen and Salter, 2004), firms in non-metropolitan regions that collaborate with universities might do so while collaborating with other organisations beyond their region.

3. Methodology

3.1. Case selection

A multiple case study (Eisenhardt, 1989; Eisenhardt and Graebner, 2007) was developed to explore the processes behind the initiation and unfolding of industry–university collaboration for innovation among seven SMEs operating in sectors that have not traditionally relied on university research in the non-metropolitan regions of North Denmark, Rogaland (Norway) and Aveiro (Portugal). When this fieldwork was undertaken, the SMEs in North Denmark were collaborating with the region's university – namely, Aalborg University. Similarly, the Rogaland SMEs were collaborating with the University of Stavanger, and the Aveiro SMEs were collaborating with the University of Aveiro. The cases were selected with the goal of exploring the influence of factors related to the initiation and unfolding of industry–university collaboration among firms in non-metropolitan regions. The case firms had to be typical of firms in non-metropolitan regions in terms of their size and sectoral characteristics. Thus, they were selected if they were SMEs – that is, if they employed a workforce equal to or below 250 employees at the time of the study or when they began collaborating with the focal university, if records were available. The firms should not have operated either in branches corresponding to the 2-digit level codes of NACE rev. 2, which Drejer and Østergaard (2015) classified as high-tech manufacturing (i.e. 21 and 26 codes) and knowledge-intensive services (i.e. 50–51, 58–66, 69–75, 78, 80, 84–93 codes). Firms in these sectors were expected to traditionally rely on university research; therefore, they were excluded from the case selection (see Table A1, in the Appendix).

Additional case studies of SMEs in metropolitan regions of Denmark, Norway and Portugal (i.e. the metropolitan regions of Copenhagen, Oslo and Lisbon)

collaborating with universities in the same or another metropolitan region[4] were also selected for comparison. When searching for SMEs in metropolitan regions, to maximise comparability with the non-metropolitan cases, the goal was also to identify firms operating in sectors that traditionally have not relied on university research. Note, however, that among the metropolitan firms that finally could be approached, two of them were operating in sectors that have traditionally relied on university research (DK4 M and PT3 M, see Table 1.2). Following a theoretical replication logic (Yin, 2014), the objective was to select metropolitan cases that differed in one key trait from the non-metropolitan cases – that is, their location in metropolitan regions. The purpose of this case selection strategy was to highlight any industry–university collaboration processes specifically involving firms in non-metropolitan regions.

In all cases, the focal SME was engaging in collaborative research projects aimed at supporting the firm's innovative activities with science, technology, engineering and mathematics (STEM) researchers employed at the partner university. Owing to the high degree of relational involvement in these firm–university links (Perkmann and Walsh, 2007), it was possible to track down how they started and unfolded over time. Using Perkmann and Walsh's (2007) classification of university–industry links, the relation of interest was defined as collaborative research, since this involves arrangements where firms and universities pursue joint R&D work. Arrangements where there was no joint R&D work, such as contract research and consultancy services commissioned by industrial clients, would not be counted as

[4] The case in the Oslo region was a firm collaborating with the University of Bergen – that is, a university outside the Oslo metropolitan region. It was not possible to find cases in the Oslo region that met the size and sectoral criteria and were collaborating with universities in the same region.

collaborative research. Note, however, that two cases (DK1 NM and NO1 NM, see Table 1.1; DK5 M, see Table 1.2) involved firms employing an industrial PhD or postdoc. Based on Perkmann and Walsh's (2007) classification, these industry–university links would be classified as human resource transfer activities due to their educational focus; yet they would also count as collaborative research due to the firm's and university's joint commitment to R&D work.

In Rogaland, the cases were approached through the managers in charge of external relations in the University of Stavanger's Faculty of Science and Technology, and the case studies in Aveiro and the Lisbon metropolitan region were approached through the University of Aveiro's technology transfer office. It was not possible to approach firms in the Oslo metropolitan region through managers or academics from the University of Stavanger; therefore, a search for cases was carried out through the research project database of the Norwegian Research Council, which is the main public funding organisation for R&D-based research projects in Norway (Norwegian Research Council, n.d.). This procedure resulted in the selection of case NO3 M. In Denmark, it was not possible to approach firms and researchers involved in collaborations through the liaison officers available at Aalborg University. To identify firms involved in collaborative research with Aalborg University, the Technical University of Denmark and the University of Copenhagen, it was necessary to perform a search through the websites of these universities[5]. The non-metropolitan firms that were finally

[5] The Technical University of Denmark and the University of Copenhagen were chosen because the former is the Copenhagen metropolitan region's technical university and the latter is the largest university in Denmark (Drejer and Østergaard, 2017, p. 1196).

approached were collaborating with Aalborg University, while the metropolitan firms were collaborating with the Technical University of Denmark.

Including cases from more than one non-metropolitan region and more than one country would increase the external validity of the case study (Yin, 2014), as this would allow for assessing the extent to which the processes observed might be relevant in non-metropolitan firms across several countries, rather than being shaped by country-specific factors. The goals of the multiple case study, thus, can be placed in between the categories of contextualised explanation and theory building as defined by Tsang (2013). As in case studies aimed at offering contextualised explanations, the case studies in this research were aimed at providing causal explanations that would be sensitive to their specific context. However, because the data were gathered from firms in three countries, with their specific national contexts, the case study was also aimed at developing explanations that would be transferable to more than one context, as in the theory-building case studies defined by Tsang (2013).

Table 1.1 Data sources, non-metropolitan cases

	DK1 NM	DK2 NM	DK3 NM	PT1 NM	PT2 NM	NO1 NM	NO2 NM
Total number of interviews	1	1	2	3	3	3	2
Interviewees from focal firms (interview mode)	Industrial PhD DK1 NM (Skype)	CTO/Co-owner DK2 NM (Telephone)	CEO; Former CEO/Owner DK3 NM (Face to face)	CEO; HR manager PT1 NM (Face to face)	Innovation director PT2 NM (Face to face)	CTO NO1 NM (Face-to-face); CEO NO1 NM (Skype)	CEO NO2 NM (Skype); Managing director partner firm NO2 NM (Face-to-face)
Role of interviewees from focal firms in the collaboration	Carrying out research work for the firm and the university as part of his/her industrial PhD and, later on, postdoc	Coordinating research work at the firm and collaboration with the university in general	Both: Coordinating research work at the firm and collaboration with the university in general	CEO: Coordinating research work at the firm and collaboration with the university in general	Coordinating research work at the firm and collaboration with the university in general	CTO: Industrial PhD. Coordinating research work at the firm and collaboration with the university in general. CEO: Accessing support funds	Both: Coordinating research work at the firm and collaboration on projects with the university
Interviewees from focal universities (interview mode)	No	Same as focal firm, external lecturer at university	No	Researcher PT1 NM, Mechanical Engineering Dept (Face-to-face)	Researcher PT 2 NM, Mechanical Engineering Dept (Face-to-face)	Researcher NO1 NM, Mechanical Engineering Dept (Face-to-face)	No
Document data	Press clippings, project description on funding organisation website, reports from company website	Press clippings, project description on funding organisation website, reports from company website	Press clippings, reports from company website	Press clippings, internal reports	Reports from company website	Press clippings, reports from company website	Reports from company website
Type of university (main university)	Comprehensive with technical character (Aalborg University, AAU)	Comprehensive with technical character (Aalborg University, AAU)	Comprehensive with technical character (Aalborg University, AAU)	Comprehensive with technical character (University of Aveiro, UA)	Comprehensive with technical character (University of Aveiro, UA)	Comprehensive with technical character (University of Stavanger, UiS)	Comprehensive with technical character (University of Stavanger, UiS)
Type of STEM department involved in the collaboration	Department of Materials and Production, Faculty of Engineering and Science	Department of Materials and Production, Faculty of Engineering and Science	Department of Planning, Faculty of IT and Design	Mechanical Engineering Department (no faculties)	Mechanical Engineering Department (no faculties)	Department of Mechanical and Structural Engineering and Materials Science, Faculty of Science and Technology	Department of Energy and Petroleum Engineering, Faculty of Science and Technology

Table 1.2 Data sources, metropolitan cases

	DK4 M	DK5 M	PT3 M	NO3 M
Total number of interviews	2	1	2	1
Interviewees from focal firms (interview mode)	CEO DK4 M (Skype)	CEO; COO DK5 M (Face-to-face)	Head Water department PT3 M (Face-to-face)	Innovation manager NO3 M (Skype)
Role of interviewees from focal firms in the collaboration	Coordinating research work at the firm and collaboration with the university in general	Both: Coordinating research work at the firm and collaboration with the university in general	Coordinating research work at the firm and collaboration with the university in general	Coordinating research work at the firm and collaboration with the university in general
Interviewees from focal universities (interview mode)	No	No	Researcher PT 3 M, Biology Dept. University of Aveiro (Face-to-face)	No
Document data	Press clippings, project description on funding organisation website, reports from company website	Press clippings, project description on funding organisation website, reports from company website	Reports from company website	Press clippings, reports from company website
Type of university (main university)	Technical (Technical University of Denmark, DTU)	Technical (Technical University of Denmark, DTU)	Comprehensive with technical character (University of Évora, UE)	Comprehensive (University of Bergen, UiB); Norwegian water research institute, University of Stirling
Type of STEM department involved in the collaboration	National Institute of Aquatic Resources (no faculties)	Department of Mechanical Engineering (no faculties)	Department of Biology, School of Sciences and Technology	Faculty of Mathematics and Natural Sciences

3.2. Data sources

The data sources in each case were semi-structured interviews and document data, including internal reports, press clippings and information available on the firms' websites. The interviewees were labelled according to their role at the firm or university and the case in which they participated. For instance, "Owner DK3 NM" refers to the owner of the firm interviewed in the third Danish case (i.e. DK3 NM). The interviews were conducted mainly with top managers responsible for coordinating research work at their firm and collaboration with the focal university in general (i.e. beyond specific projects). However, one interviewee (Industrial PhD DK1 NM) had collaborated as an industrial PhD and was pursuing an industrial postdoc at the time of the interview. Another interviewee (CTO NO1 NM), at the time of the interview, was collaborating as an industrial PhD while also coordinating research work at the firm and collaboration with the university. In cases PT1 NM, PT2 NM, NO1 NM and PT3 M, semi-structured interviews were also conducted with university researchers who had collaborated on research projects with the case firms. This was done to gather information that firm managers could not provide (see Table 1.1). The document data enabled the triangulation of data gathered from the interviews and provided additional information about the firms' characteristics as well as the histories of their relationships with university partners.

Interviews with the Portuguese firm managers and researchers were conducted between April and June 2018, and follow-up interviews were carried out in June 2019 to gather more information about firms PT1 NM and PT2 NM (interviews with CEO PT1 NM and Researcher PT2 NM). As for the Danish and Norwegian cases, interviews with firm managers were carried out between April and June 2019. The interviews were conducted face-to-face whenever possible; however, Skype and

phone conversations had to be arranged in 6 out of 21 instances. The interviews lasted between 30 and 90 minutes, and the interview guide (see Appendix) contained questions on the current status of the collaboration with the university as well as follow-up questions intended to explore how the relationship had started (Rubin and Rubin, 2005, pp. 137–146). Whenever the first interviewee could not recall how the relationship began, document data or interviews with other managers and researchers supplemented information on the initiation of these links. All interviews were recorded and transcribed, and notes were taken during the interviews.

3.3. Research process

Similar to other multiple case studies involving firms (Gilbert, 2005; Graebner and Eisenhardt, 2004), this investigation was informed by previous research, which aided in identifying factors that could influence processes that facilitate the initiation and unfolding of industry–university collaboration in non-metropolitan regions.

Previous research highlighted factors that could influence the industry–university collaboration process and whose influence could differ among different types of regions. These were (i) the propensity of universities in non-metropolitan regions to support innovation and development in regional industries through education and research activities (Guerrero and Evers, 2018); (ii) the educational and research actions through which these universities support regional industries (Guerrero and Evers, 2018); (iii) the observation that firms that employ university graduates are more likely to collaborate with university graduates, as these graduates provide firms with the capacity to acquire and assimilate university knowledge (Drejer and Østergaard, 2017; Laursen and Salter, 2004); (iv) the observation that firms in non-

metropolitan regions might look to extra-regional collaboration channels to access suitable collaboration partners (Drejer and Vinding, 2007; Fitjar and Rodríguez-Pose, 2011; Grillitsch and Nilsson, 2015; Jakobsen and Lorentzen, 2015); (v) the finding that firms that access public funding are more likely to collaborate with universities (Mohnen and Hoareau, 2003; Segarra-Blasco and Arauzo-Carod, 2008); and (vi) the observation that geographical proximity is positively associated with industry–university collaboration (D'Este and Iammarino, 2010).

The factors reviewed in the literature were taken into account in the design of the interview guides for firm managers and university researchers. They explored, in the following order, (i) goals of the collaboration between the case firm and university, (ii) how the industry–university collaboration started and (iii) how this collaboration unfolded. Those factors that were easier to convey to the interviewees were made explicit in the interview guide, whereas those that were more difficult to convey were covered as the interview unfolded. The interview guides are provided in the Appendix.

This was a case study aimed at exploring whether and how factors highlighted by the literature as relevant to industry–university collaboration are positively associated with the initiation and unfolding of the industry–university collaboration process. Accordingly, when coding the interview transcripts and documents, the factors highlighted as relevant to industry–university collaboration in the literature also facilitated exploring what had influenced the formation of a relationship between the focal firm and university and how this relationship unfolded later on. Thus, special attention was paid in the first-order codes to paragraphs in the interviews and document data where these factors appeared to be relevant. Later on, first-order process-oriented codes were aggregated into theoretically laden

themes following inductive theory development methods (Gilbert, 2005; Gioia et al., 2013; Saldaña, 2009). It should be noted that directing the coding process at factors highlighted in the literature as relevant to industry–university collaboration came at the expense of other potential factors not highlighted in the literature.

First, tabular displays were used to explore the influence of factors extracted from the literature review at the start of the relationship between each firm–university pair and at later stages. Second, cross-case comparisons were carried out to uncover similarities among the non-metropolitan cases. Third, cross-case comparisons between the metropolitan cases and non-metropolitan cases were conducted to highlight which processes appeared to be specific to industry–university collaborations in non-metropolitan regions (Eisenhardt, 1989; Eisenhardt and Graebner, 2007; Gilbert, 2005). Thus, the study approach combined literal and theoretical replications to uncover processes which were common among the non-metropolitan cases, regardless of factors specific to the context of each non-metropolitan region and country, and how different they were from metropolitan cases (Tsang, 2013; Yin, 2014).

4. Context

4.1. National industry–university collaboration policies

Considerable similarities exist between Danish and Norwegian industry–university collaboration policies, whereas these policies are arguably less supportive of industry–university collaboration in Portugal, as will be discussed below.

In Denmark, the implementation of a new university law in 2003 and the launch of the Danish Globalisation Strategy in 2006 meant a greater policy emphasis on third mission activities as well as a stronger emphasis on performance-oriented funding at the expense of basic funding (Fagerberg and Fosaas, 2014, p. 32; Kalpazidou Schmidt, 2012). Development contracts between the Ministry of Higher Education and Science (previously the Ministry of Science, Technology and Innovation) and universities have focused since 2010 on research performance indicators, such as the number and level of publications, but also on indicators of industry–university collaboration, such as the amount of external funds. These developments have been similar in Norway, where a formula-based funding system for education and research was introduced in 2002 that placed greater emphasis on educational outcomes and research performance (Kalpazidou Schmidt, 2012).

Similarly, both countries have a comparatively generous range of public funding schemes to support firm innovation and collaboration between firms and universities. These policies include the following:

- Network-based initiatives, such as the establishment in Denmark of 22 sector-based innovation networks and cross-sectoral innovation platforms (Knudsen et al., 2018), and schemes supporting the development of emerging, mature and internationally oriented clusters in Norway (Solberg, 2016).

- Schemes promoting firms' absorptive capacity and linkages with research organisations. In Denmark, this umbrella includes Innobooster, which helps SMEs in hiring university-trained employees, or innovation vouchers which help SMEs purchase researcher services from universities. In Norway, various public funding schemes stimulate collaboration for innovation, with the Norwegian Research Council supporting R&D-based innovation activities and Innovation Norway focusing in non-R&D innovation (Knudsen et al., 2018; Solberg, 2016).
- Industrial PhD and postdoc programmes, with Denmark introducing industrial PhDs in 1970 and Norway following in 2008 with an industrial PhD programme inspired by that of Denmark (Grimpe, 2015; Solberg, 2016). In Denmark, an impact assessment conducted in 2011 concluded that the scheme increased firms' absorptive capacity while stimulating industry–university links (Grimpe, 2015). Similar results stemmed from an evaluation of the Norwegian industrial PhD programme conducted in 2012, although the review also pointed out that the programme had to be communicated further to firms and researchers (Solberg, 2016).

In contrast with its Scandinavian counterparts, the Portuguese policies are less supportive of industry–university collaboration, in part, because of the Portuguese economic context. Firms and universities have a relatively scarce tradition of cooperation. Low levels of absorptive capacity in the industrial fabric and effects of the economic crisis that have lingered for most of the past decade have further hampered industry–university links. Although public sector R&D spending decreased substantially between 2010 and 2014 owing to government budgetary cuts, the largest reduction in levels of R&D spending took place in the private

sector. In recent years, policies have been implemented to stimulate industry–university links, including collaborative R&D networks encompassing R&D projects promoted by employers' associations and implemented by universities, and cluster initiatives. This policy framework is strongly reliant on a supply-side approach, thus paying limited attention to the needs of firms. An exception to this supply-side bias might be using tax incentives to develop R&D (Corado Simões et al., 2018; Mira Godinho and Corado Simões, 2015). Yet, in a context marked by severe budgetary restrictions like that of Portugal, European Union (EU) cohesion policy funding for Smart Specialisation strategies or the FP7 and H2020 programmes might play a relevant role in supporting collaboration for innovation projects (Corado Simões et al., 2018; Mira Godinho and Corado Simões, 2015; Silva et al., 2016).

4.2. Context of the regions and universities

As Table 2 shows, North Denmark, Rogaland and Aveiro host a smaller number of main university campuses than their metropolitan counterparts. More importantly, in these regions, a smaller percentage of the population is enrolled in universities compared to metropolitan regions. Therefore, universities provide education to a smaller percentage of the local population in non-metropolitan regions. There are also substantial inter-regional differences in the workforce proportion holding a university degree. As metropolitan regions are home to multiple universities and governmental organisations, the presence of these organisations might partially explain why a larger percentage of metropolitan region populations hold a university degree. Finally, in non-metropolitan regions, a smaller proportion of the workforce is employed in medium and high-technology manufacturing and knowledge-intensive services compared to metropolitan regions, as measured according to the Regional Innovation Scoreboard.

Table 2 Regional characteristics

	Norway		Denmark		Portugal	
	Oslo metropolitan region	Rogaland	Copenhagen metropolitan region	North Denmark	Lisbon metropolitan region	Aveiro region
1. Population, 2017	1,271,127	472,024	1,807,404	587,335	2,821,349	363,752
2. Population density, 2017. Inhabitants/km^2	252.5	53.5	745.4	76.2	1,006.2	221.5
3. Number of universities per region	3	1	5	1	5	1
4. Students enrolled at the local universities, latest data available	56,070	12,000	79,214	19,926	111,294	13,000
5. Students enrolled at the local universities, as a percentage of the population	4.41%	2.54%	4.38%	3.39%	3.94%	3.57%
6. Percentage of firms that reported collaborating with universities between 2014 and 2016 (all of Norway; between 2012 and 2014 for the Danish regions due to data limitations)	20%		16.53%	20.41%	10.30%	10.30%
7. Percentage of the 25–64 age group with tertiary education, average 2007–2017 (Levels 5–8 ISCED 2011)	50.41%	35.63%	45.60%	28.21%	26.44%	16.56%
8. Percentage of the 25–64 age group with tertiary education, 2017 (Levels 5–8 ISCED 2011)	54.30%	39.80%	50.20%	31.70%	32.60%	22.50%
9. Percentage of the 25–64 age group with tertiary education, percentage increase 2007–2017 (Levels 5–8 ISCED 2011)	7.90%	7.60%	9.30%	8.20%	12.10%	10.70%
10. Employment in medium and high-technology manufacturing and in knowledge-intensive services as a percentage of the workforce. Score from the Regional Innovation Scoreboard 2017, compared to EU average 2011 (EU average 2011 = 100. Source: European Commission, 2019)	144.7	100.91	158.39	80.84	120.07	43.44

Sources: Rows 1, 2, 5: Eurostat (n.d.). Row 3: Bonfim et al. (2013); Danish Ministry of Higher Education and Science (n.d.), Government.no (n.d.). Rows 4, 5: Websites of the universities located in each region. Row 6: Direção-Geral de Estatísticas da Educação e Ciência (n.d.), Statistics Norway (n.d.), own elaboration from Statistics Denmark microdata. Rows 7 to 9: Eurostat (n.d.). Row 10: European Commission (2019). Data for the Copenhagen metropolitan region correspond to the Capital Region of Denmark. Rows 1, 2, 6–10: Data for the Oslo metropolitan region correspond to the counties of Oslo and Akershus. Rows 6–10, data for Rogaland correspond to the sum of the Rogaland and Agder counties, and data for Aveiro correspond to the broader Centro Region.

The qualitative evidence also points to the non-metropolitan regions specialising in sectors that have not traditionally relied on university research, relative to the national economy. This is the case of machinery manufacturers in North Denmark and Rogaland and fabricators of metal products in Aveiro (Nilsson, 2006; Pedersen, 2005; Rodrigues and Teles, 2017; Teles et al., 2014). A similar percentage of firms collaborate with universities regardless of regional location, and more firms collaborate with universities in North Denmark than in the metropolitan region of Copenhagen.

The three non-metropolitan universities included in the present case study are young higher education institutions. The University of Aveiro was founded in 1973 (Nieth et al., 2018), Aalborg University in 1974 (Guerrero and Evers, 2018) and the University of Stavanger in 1994 as a university college, acquiring full university status in 2005 (Alpaydin et al., 2018). These universities have oriented their education and training activities to support innovation in regional firms and are regarded in their home regions as crucial innovation partners (Alpaydin et al., 2018; Fonseca and Çinar, 2017; Guerrero and Evers, 2018). In that regard, they differ from other universities in non-metropolitan regions that have not developed strong links with local firms (Boucher et al., 2003).

The origins of these higher education institutions are also connected to the regional firm demography at the time. The first premises of the University of Aveiro were at the Innovation Centre of Portugal Telecom, also launched in the early 1970s, and some of the first educational degrees awarded by the university were in the domains of electronics and communications and in disciplines related to sectors dominant in the region at that point in time, such as ceramics and materials for the ceramics industry, environment and marine sciences and technologies for

fisheries, and natural and agro-food products for agriculture and farming (Fonseca and Çinar, 2017; Rodrigues and Teles, 2017). Similarly, the academic institutions that preceded the University of Stavanger developed educational degrees to cater to the needs of the growing oil and gas industry, which is currently the main economic sector in the region[6] (Alpaydin et al., 2018). Lastly, Aalborg University started as a merger of an engineering academy and other higher education institutions, with a strong focus on engineering and science degrees. Shortly after its foundation, it oriented its educational and research activities towards meeting the needs of the emerging information and communications technology (ICT) sector. Indeed, at its launch, the university had two departments in electronic engineering and employed 200 academic staff members. In 1979, the university founded the Department of Electronic Systems to train students according to the needs of this sector (Guerrero and Evers, 2018).

Over time, these higher education institutions have developed educational and research activities that support the aforementioned sectors through links, such as research centres, science parks and cluster initiatives. These links, in turn, have contributed to the research excellence of Aalborg University in ICT (Guerrero and Evers, 2018), the University of Aveiro in building materials and ICT (Rodrigues and Teles, 2017) and the University of Stavanger in oil and gas (Alpaydin et al., 2018). These universities also endeavour to support the growth of new economic sectors in their home regions, with examples such as biomedical sciences at Aalborg University (Guerrero and Evers, 2018), aquaculture and marine biotechnology at

[6] Two of the academic institutions that would become part of the University of Stavanger (a regional college and a technical college) had already been offering degrees related to oil exploration since the 1970s (Alpaydin et al., 2018, p. 17).

the University of Aveiro (Rodrigues and Teles, 2017) and biomedicine and geothermal and offshore wind energy at the University of Stavanger (Alpaydin et al., 2018).

Beyond specific sectors, the three universities have committed considerable resources to activities for supporting innovation in regional firms, which can be readily accessible to SMEs from sectors not traditionally reliant on university research. These include student projects carried out in collaboration with firms and the development of intermediaries aimed at helping SMEs access consultancy services (Alpaydin et al., 2018; Fonseca and Çinar, 2017; Guerrero and Evers, 2018; Nieth and Benneworth, 2019; Rodrigues and Teles, 2017). For instance, Aalborg University's problem-based learning (PBL) approach to learning entails that students work in teams on self-defined, interdisciplinary projects, many of them related to challenges faced by local firms. Through these projects, firms can screen suitable candidates for their workforce, and PBL projects have increased the interest of SMEs in hiring Aalborg University graduates (Gregersen et al., 2009). The number of projects grew to the point that, in recent years, Aalborg University has continuously hosted between 2,000 and 3,000 of them (Kendrup, 2006, p. 25), and in 2016, 53.1% of the master's theses were done in collaboration with firms or other external partners (Aalborg University, 2016).

Note that the case universities' involvement in regional development has also been stimulated by their interactions with regional policymakers and the funding sources that might come from these interactions. On that note, the University of Aveiro worked with the local municipalities to define the region's development strategy (Rodrigues and Teles, 2017), and some of Aalborg University's third mission activities have received monetary support from North Denmark's Growth

Forum – a multi-stakeholder economic governance body in charge of determining the allocation of regional development funds – as part of a knowledge dissemination agreement between these two parties (Lindqvist et al., 2012). An example is the funding that the Growth Forum provided for the establishment of the matchmaking network – a network of Aalborg University researchers, public and private sector officials and students aimed at facilitating firms' access to the university's research and educational services, in particular SMEs in the outermost areas of the region of North Denmark, with limited connections to Aalborg University (Nieth and Benneworth, 2019).

5. Analysis

5.1. Case overview

Tables 3.1 and 3.2 present an overview of the analysed cases. At the time of the interviews, all but two firms could be considered SMEs. The exceptions are the firms in DK5 M and PT1 NM, yet these firms did not have more than 250 employees at the beginning of their relationship with the focal university. Another important similarity among the cases is that most of them had an R&D department by the time the interviews were conducted; PT1 NM and NO2 NM were the only exceptions. That most of the non-metropolitan case firms have an R&D department is in accordance with the expectations of the industry–university collaboration literature, because firms with R&D departments have been found to be more likely to collaborate with universities (Laursen and Salter, 2004). The possession of R&D departments might partially explain why these firms began and continued collaborating with universities. Section 5.5. will explore this point in depth. That most of the case firms have an R&D department becomes even more important when considering that these firms operate in sectors where R&D and university research have traditionally not played an important role in the development of new products, such as the manufacturing of components for the maritime industry (DK1 NM), the manufacturing of fabricated metal products (PT1 NM) or the manufacturing of machinery for oil and gas operators (NO1 NM, NO2 NM).

Table 3.1 Characteristics of non-metropolitan cases

	DK1 NM	DK2 NM	DK3 NM	PT1 NM	PT2 NM	NO1 NM	NO2 NM
Main activity at the focal firm	Machinery manufacturer for the maritime industry	Manufacturer of devices for people with special mobility needs	Furniture manufacturer for the public sector	Manufacturer of fabricated metal products	Manufacturer of refrigerators for restaurants, hotels and supermarkets	Machinery manufacturer for oil & gas operators	Machinery manufacturer for oil & gas operators
NACE industry code	28. Manufacturer of machinery and equipment n.e.c.	30. Manufacturer of other transport equipment	31. Manufacturer of furniture	25. Manufacturer of fabricated metal products, except machinery and equipment	28. Manufacturer of machinery and equipment n.e.c.	25. Manufacturer of fabricated metal products, except machinery and equipment	28. Manufacturer of machinery and equipment n.e.c. (Partner firm: 09. Mining support service activities)
Type of collaboration with the focal university	Industrial postdoc	Collaborative research project	Collaborative research project	Collaborative research project	Collaborative research project	Industrial PhD	Collaborative research project
Number of employees	~100	80	25	420–430 (200–250 beginning links with UA)	220–230	10	28
R&D department	Yes	Yes	Yes	No	Yes	Yes	No
Year of establishment	1917	2002	1990	1965	1995	1986	2010

The following analysis of the case studies will begin with a discussion of the actions that facilitated the initiation of relations between the case firms and universities. This will be followed by an analysis of how these relationships unfolded over time. The cross-case comparison will uncover how the factors mentioned in section 3.3. influenced the initiation and unfolding of the relationships between the case firms and universities.

Table 3.2 Characteristics of metropolitan cases

	DK4 M	DK5 M	PT3 M	NO3 M
Main activity at the focal firm	Manufacturer of water quality sensors for fish farming	Machinery manufacturer for the food industry	Consultancy specialising in hydraulic engineering	Manufacturer of water treatment equipment
NACE industry code	26. Manufacturer of computer, electronic and optical products	28. Manufacturer of machinery and equipment n.e.c.	71. Architectural and engineering activities; technical testing and analysis	46. Wholesale trade, except of motor vehicles and motorcycles
Type of collaboration with the focal university	Collaborative research project	Industrial postdoc	Collaborative research project	Collaborative research project
Number of employees	50–53	380 (150 beginning links with DTU)	56	230
R&D department	Yes	Yes	Yes	Yes
Year of establishment	1987	1987	1996	Mid-1990s

5.2. Processes facilitating the start of industry–university relations

A pattern emerged among four of the seven non-metropolitan cases, where the firms had been approached through outreach activities organised by the focal university (see Table A2.1 in the Appendix). In DK1 NM and PT2 NM, it was a researcher from the focal university who had approached the firm. In PT2 NM, researchers from the University of Aveiro were developing research on new refrigeration technology and needed a private partner that could help them with

practical tests. Information from students who had carried out projects with the firm suggested that the firm had the competencies required to take part in the tests, since it had been conducting research on conventional refrigeration technology. After this first contact, the firm signed a support letter to help the university obtain the necessary funds to develop a research centre devoted to refrigeration technology.

Researcher PT2 NM: "We contacted the enterprise [in 2008] to see if they were interested in going ahead with [...] development work on this new technology. That's true that they are working [...] with the conventional technology. [...] We had some previous contacts, as some of our students were doing their projects with them."

In DK2 NM and PT1 NM, the contact started because managers from the focal firm participated in an event organised by the focal university. At one of these events (PT1 NM), the managers from the focal firm became acquainted with the manager of the University of Aveiro's technology transfer office. This manager would, in turn, facilitate approaching researchers from the mechanical engineering department. After this first contact, the firm would approach these researchers for consultancy projects, such as the development of a piece of aluminium for a German manufacturing multinational corporation (MNC) (see section 5.4.).

CEO PT1: "In 2009, I was at the first session on university–industry collaboration. This was promoted by the Portuguese SME Institute and the University of Aveiro, where we got to know the University of Aveiro and its technology transfer office. [...] With the director of the technology transfer office, we felt there was there a department [...] that could interact with the industry."

This pattern differs from that of the metropolitan cases, where university actors did not approach the firms directly in any of the studied cases. In these cases, the first contacts occurred either because managers from the focal firm approached the university or because third-party organisations connected the focal firms with university researchers. In the case of DK5 M, the firm had approached the university as part of its employee recruitment strategy. In other cases, the initial link between the focal firm and focal university had occurred by participating in activities organised by a third party, such as taking part in a research project application made by another organisation (PT3 M) or a sectoral conference (NO3 M). For more information on the metropolitan cases, see Table A2.2 in the Appendix.

Thus, the cross-case comparison suggests that in non-metropolitan regions, actions undertaken by actors from the local university might play a key role in establishing links with firms. These first contacts can be initiated because the focal university invites firms to events aimed at establishing such links but also because researchers from the focal university approach the firm in search of suitable research partners or clients for commissioned research. Therefore, the findings point to actions through which universities could forge relationships with firms in non-metropolitan regions.

It should also be noted that among four of the seven non-metropolitan cases (DK1 NM, NO1 NM, PT1 NM and PT2 NM), university students tended to play a role in initiating the relationship between the focal firm and university (see Table A2.1 in the Appendix). In PT2 NM, students from the University of Aveiro provided to the university' researchers insights on research activities conducted at the firm where they had participated in an internship. DK2 NM helped CTO DK2 NM develop their master's (2007) and doctoral projects (2008–2010) as an Aalborg University student

by helping them build a chair for experimental research at the university, after an employee from that firm had met CTO DK2 NM at an event organised by Aalborg University in 2007. According to CTO DK2 NM, the firm wanted to learn about their knowledge by supporting their master's and doctoral projects. In 2015, the firm hired them as its new CTO.

CTO DK2 NM: "That was back in 2007... during my master's thesis, where I had some collaboration with them. I met a guy from [firm where they are currently employed] at a presentation we both attended [at the university]. [...] They helped me build a wheelchair for some experimental studies at the university."

Thus, the proactive role that non-metropolitan universities appear to play at the start of industry–university relations cannot be completely disentangled from the connections made by students from the focal university. Student projects provide an opportunity for initiating industry–university links, which might evolve later on into collaborative research.

5.3. Unfolding of the relationship between the focal firm and focal university

Among five of the seven non-metropolitan cases, the transitions to collaborative research were aided by governmental support schemes. In PT1 NM and PT2 NM, Horizon 2020 (H2020) funds from the EU helped the firms launch collaborative research projects with the University of Aveiro. PT2 NM's first links with the University of Aveiro, starting in 2008, were of an informal nature, with the firm providing a support letter for a research project application submitted by university researchers. In 2016, H2020 funds helped the firm implement research projects involving joint R&D work with the University of Aveiro.

Innovation director PT2 NM: "I knew there were H2020 incentives to do small research projects. [...] They were projects of 15,000–20,000 euros that could be materialised in one year, and we started there in December 2016 with the team we have now."

Among the other non-metropolitan cases (DK1 NM, DK3 NM and NO1 NM), national funding sources supported the transition to collaborative research. NO1 NM began its relationship with the University of Stavanger in 2011 by hosting student projects; students helped the firm solve technical problems posed by customers on product performance. In 2017, the firm's CEO proposed that the firm's CTO pursue an industrial PhD at the University of Stavanger and apply for national funds to finance the industrial PhD.

CTO NO1 NM: "So, I got the contact of [researcher NO1 NM] at the time I started, so I went to the university. [...] [In 2017] my boss came to me. I think [my boss] had had a meeting at Innovation Norway and learned that it was possible to do an industrial PhD."

Thus, among the non-metropolitan cases, firm–university links evolved from non-collaborative relationships, such as human resource transfer and commissioned research activities, to collaborative research, where both parties supplied R&D work (Perkmann and Walsh, 2007). While this collaborative research took the form of industrial PhDs in some cases, in others, the firms became involved in research projects. In addition, cross-country differences are visible in the type of public funding sources that firms could obtain, with EU H2020 funds supporting collaborative research among the Portuguese non-metropolitan cases and national funding sources being more common in the Scandinavian cases. That national funds supported the transition to collaborative research in the Danish and

Norwegian cases, but not in the metropolitan cases, might be related to the greater abundance of national public funds supporting industry–university relations in Denmark and Norway. However, it should be noted that EU structural funds have been relevant in supporting innovation projects in North Denmark (Growth Forum North Denmark, 2016).

The pattern among the non-metropolitan cases is similar to that of the metropolitan cases. In two out of four metropolitan cases, relationships between the focal firms and universities tended to start as publicly funded collaborative research (PT3 M and NO3 M), as shown in Table A3.2 in the Appendix.

5.4. Role of organisations other than universities

Among five of the seven non-metropolitan cases (DK1 NM, PT1 NM, PT2 NM, NO1 NM, NO2 NM; see Table A4.1 in the Appendix), becoming more attractive to international customers appears to be a reason for the unfolding of industry–university relations into collaborative research. As in PT2 NM, customers demand new or improved products; this, in turn, incentivises the firm to increase its product development capabilities, generating greater interest in the firm in industry–university collaboration.

Innovation director PT2 NM: "[In energy efficiency] We started with Denmark, Norway, Sweden... [in 2009] they wanted to risk, and many are still with us. [...] We managed in 2011 that our biggest client [...] shifted to energy efficiency. [...] [The current project with the University of Aveiro] has brought many ideas that are being applied to the products, and we have managed to reduce energy consumption a lot, which puts us at the level of the great European producers."

In other cases, like NO1 NM or NO2 NM, the focal firm had to offer products to international customers of sufficiently credible technical standards, and collaboration with university researchers helped the firm assess via scientific research the credibility of the product or develop technical expertise through an industrial PhD.

CTO NO1 NM: "From my boss' part, when they looked at it [the industrial PhD] for first time, I think they saw the opportunity to go in depth into the technical issues, because if we want to expand in the world, we need a stronger technical background. […] And that's also what we see when we go especially to Germany, maybe Holland too."

Among the metropolitan cases, pressure from international competitors incentivised the firms to engage in collaboration with universities. In DK4 M and DK5 M, competition from large foreign firms incentivised the firms to increase their research capabilities, turning human resource transfer links between these firms and the focal universities into collaborative research. Therefore, the metropolitan case firms also appear to have transferred their relationships with universities to collaborative research in order to be attractive to international customers (see Table A4.2 in the Appendix for details).

5.5. Non-metropolitan firms with R&D departments

As mentioned in section 5.1., five out of seven non-metropolitan case firms had R&D departments when the interviews were conducted. During the interviews, it was reported that some of these firms (DK1 NM and PT2 NM) had already had R&D departments when the relationship with the case university started. As shown in Tables A4.1 and A5.1 in the Appendix, R&D departments appear to have contributed to the unfolding of the relationships between the non-metropolitan

case firms and universities. In DK1 NM, being desirable to international customers had incentivised the firm to invest in research, and to separate the R&D department from the project department. The same goal, in turn, incentivised the firm to enhance its relationship with universities to full-fledged collaborative research.

Industrial PHD DK1 NM: "Now they have separated the project and research department, so projects are now focusing on delivering projects, and the research department is focusing on research. […] New regulations mean that customers have problems with the engines. How can we cope with the problems? And can we be better than the competitors? So, in that sense, you can also say that the customers drive the research."

In DK2 NM, one of the stated goals for the hiring of an R&D manager was to "intensify [DK2 NM] cooperation with educational institutions" (Press clipping, DK2 NM). And in NO1 NM, the firm had invested increasing resources in R&D along with the unfolding of its relationship with the University of Stavanger. Indeed, through the industrial PhD, the firm's CTO was able to increase their skills, and the contribution of the R&D department to the firm's innovation strategy.

Thus, the findings indicate that the absorptive capacity that R&D departments provide (Laursen and Salter, 2004) played a role in the unfolding of collaborations between the non-metropolitan case firms and universities. The R&D departments enhanced the non-metropolitan case firms' ability to develop new products and be attractive to international customers. At the same time, the R&D departments helped the firms integrate university knowledge, and the evidence suggests that the non-metropolitan case firms invested increasing resources in their R&D departments while they increased their collaboration with their university partners.

6. Discussion

This paper builds on previous research by the author and other researchers (Drejer and Østergaard, 2017; Guerrero, 2020a, 2020b; Guerrero and Evers, 2018; Laursen and Salter, 2004; Mohnen and Hoareau, 2003) on what characteristics are positively associated with industry–university collaboration. This section discusses a set of propositions based on the case study findings and employs these propositions to develop a model of factors that can influence the initiation and unfolding of industry–university collaborations in non-metropolitan regions (Figure 1). In principle, the case selection strategy limits the transferability of the findings to larger firms and firms from sectors that traditionally have not relied on university research.

First, the case study findings relate to the characteristics of the focal non-metropolitan universities. Non-metropolitan universities have a strong propensity to cultivate links with regional firms through their educational and research activities (Alpaydin et al., 2018; Fonseca and Çinar, 2017; Guerrero and Evers, 2018; Nilsson, 2006; Rodrigues and Teles, 2017) and, as shown in the case studies, the outreach actions taken by these universities have led to the start of relationships with the case firms. Outreach actions might include events organised by the management of the focal university to promote industry–university collaboration but also actions taken by researchers from the focal university, such as searching for potential collaboration partners in the private sector. Thus, a first proposition can be formulated:

Proposition 1.1: Industry–university collaboration in non-metropolitan regions is likely to be initiated through the university reaching out to firms.

Second, the proactive role that non-metropolitan universities appear to play in the initiation of industry–university links cannot be completely disentangled from the connections established by students from the focal university. When seeking potential collaboration partners, researchers from non-metropolitan universities can tap into the information provided by university students on the firms where they have completed internships. Students can also be the first contact that initiates relationships between firms and universities, as they solve through their projects technical challenges that a firm faces or receive support from the firm in their student projects. The educational actions taken by non-metropolitan universities, thus, appear to provide a first, accessible contact point between firms and non-metropolitan universities, which allows the relationship to unfold. This observation corresponds to previous research findings that underlined the relevance of non-metropolitan universities' educational activities for establishing industry–university collaboration (Guerrero and Evers, 2018; Nilsson, 2006). Therefore, a proposition subsidiary to the first proposition can be formulated:

Proposition 1.2: In non-metropolitan regions, university students can help university actors approach non-metropolitan firms through internships or projects undertaken at the firms.

By suggesting that universities' actions are key to initiating industry–university relations in non-metropolitan regions, the model adds to previous research indicating that universities in non-metropolitan regions can be key innovation partners in these regions by committing their educational and research activities to supporting innovation in the regional business community (Alpaydin et al., 2018; Boucher et al., 2003; Evers, 2019; Fonseca and Çinar, 2017; Guerrero and Evers, 2018; Rodrigues and Teles, 2017). The findings also support the view that the

characteristics of universities matter because the universities that carried out these actions are higher education institutions with a long track record of promoting industry–university links with firms in the region (Alpaydin et al., 2018; Fonseca and Çinar, 2017; Guerrero and Evers, 2018).

Third, the case study findings suggest that governmental support schemes (national in the Danish and Norwegian cases and coming from the EU H2020 programme among the Portuguese cases) appear to support the unfolding of relationships between non-metropolitan firms and universities directed towards collaborative research. This might be so due to the R&D work investments required to expand university–firm links from non-collaborative to collaborative relationships (Perkmann and Walsh, 2007). For these firms, collaborative research with universities might demand R&D investments beyond the firms' financial resources (Bruneel et al., 2016), unless public funding can compensate for the investments that firms must make. The analysis provides insights about the stages at which governmental support schemes become relevant in the non-metropolitan cases. Thus, the model adds substance to the finding that firms that have access to government support schemes are more likely to collaborate with universities (Mohnen and Hoareau, 2003; Segarra-Blasco and Arauzo-Carod, 2008), leading to the second proposition:

Proposition 2: Public funds support the unfolding of industry–university links into collaborative research.

Fourth, previous research pointed out that collaboration with extra-regional organisations is positively associated with innovation among firms in non-metropolitan regions (Drejer and Vinding, 2007; Fitjar and Rodríguez-Pose, 2011;

Grillitsch and Nilsson, 2015; Jakobsen and Lorentzen, 2015). In the case studies, interactions with international customers (whether foreign or home-grown MNCs) appear to play a role in non-metropolitan firms' innovative practices. Contrary to the literature, however, these interactions do not involve collaborating with international customers; rather, interactions with international customers tend to occur at an arm's length, with the non-metropolitan case firms unfolding their relations with universities in order to be attractive to potential or actual international customers. Thus, a third proposition is suggested:

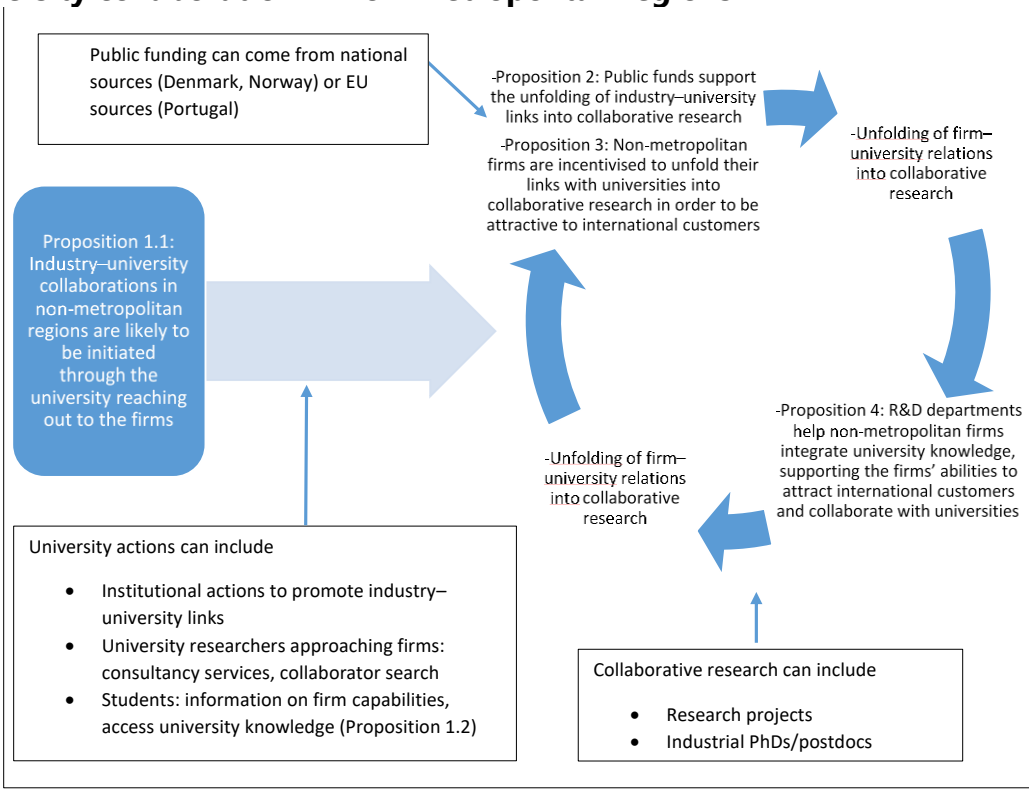
Proposition 3: Non-metropolitan firms are incentivised to unfold their links with universities into collaborative research in order to be attractive to international customers.

Fifth, the non-metropolitan case firms tend to invest increasingly in R&D along the unfolding of the collaboration with the case university despite being firms that operate in sectors where R&D investments would not be expected to be key to innovation (Pavitt, 1984). While R&D helps the non-metropolitan case firms integrate knowledge from their university partners and develop products that are attractive to international customers, these firms appear to invest increasingly in R&D in order to further benefit from the knowledge generated by their university partners. The result is a co-evolutionary process between increasing investments in R&D and the unfolding of industry–university collaborations, adding substance to the insight that firms that have R&D departments are more likely to collaborate with universities (Laursen and Salter, 2004). Therefore, the final proposition can be formulated:

Proposition 4: R&D departments help non-metropolitan firms integrate university knowledge, supporting the firms' ability to attract international customers and collaborate with universities.

Thus, the model depicts a process in which the willingness to develop products attractive internationally and the support received from public subsidies incentivises non-metropolitan firms to unfold their links with universities into collaborative research. R&D helps non-metropolitan firms integrate university knowledge, further supporting the unfolding of industry–university links. Further, developing their R&D capacity better prepares the focal firms to absorb the knowledge generated by their university partners, which supports the continuation and unfolding of their relationships with the case universities.

Figure 1 Model of factors that can influence initiation/ unfolding of industry-university collaboration in non-metropolitan regions



7. Conclusion

The present study aimed to contribute to the industry–university collaboration literature by advancing a set of propositions suggesting how factors that the literature has identified as being positively associated with industry–university collaboration might relate to the initiation and unfolding of collaborations between firms and universities in non-metropolitan regions. The model formulated in Figure 1 brings these propositions together:

Proposition 1.1: Industry–university collaborations in non-metropolitan regions are likely to be initiated through the university reaching out to firms.

Proposition 1.2: In non-metropolitan regions, university students can help university actors approach non-metropolitan firms through internships or projects undertaken at the firms.

Proposition 2: Public funds support the unfolding of industry–university links into collaborative research.

Proposition 3: Non-metropolitan firms are incentivised to unfold their links with universities into collaborative research in order to be attractive to international customers.

Proposition 4: R&D departments help non-metropolitan firms integrate university knowledge, supporting the firms' ability to attract international customers and collaborate with universities.

By virtue of their size and sectoral characteristics, the non-metropolitan case firms possess traits that are common to firms in non-metropolitan regions (Jauhiainen and Moilanen, 2012; Tödtling and Trippl, 2005, 2015). Thus, the case firms presented an interesting choice for a case study which was aimed at providing a

deeper understanding of how industry–university collaboration starts and unfolds in non-metropolitan regions. Conversely, the findings of this study are not necessarily transferable to larger firms and/or firms operating in sectors where innovation is more likely to be based on university research. Future research could explore how similar the processes are among the latter firms.

Another limitation stems from the possibility that firms doing collaborative research with universities possess traits that make them particularly likely to forge such links. Thus, the present study could be extended with cases where the focal firm had an experience of collaborative research with universities but no longer engages in such partnerships or cases where the industry–university link of interest does not demand that the firm perform R&D work, such as contract research.

Similarly, the focal firms have collaborated with universities that have a strong propensity to interact with regional firms (Alpaydin et al., 2018; Fonseca and Çinar, 2017; Guerrero and Evers, 2018). It might be worth exploring how industry–university collaborations start and unfold in non-metropolitan regions where the focal university does not have a strong regional orientation.

Finally, managers at the universities of Aveiro, Stavanger and Aalborg contacted in the present study could not provide access to firms in metropolitan regions, except for the case study in the Lisbon metropolitan area. Thus, the author had to perform searches to locate and approach firms in metropolitan regions (see section 3.1.). Approaching metropolitan firms proved considerably more difficult, resulting in the inclusion of a smaller number of metropolitan cases, and firms from sectors where university research might play a relatively important role, relative to non-metropolitan firms. Future research should tap into collaborative research with researchers located in metropolitan universities to approach metropolitan firms.

Despite these limitations, the findings from the case studies provide the literature with a model of factors that can influence the initiation and unfolding of industry–university collaboration in non-metropolitan regions. Furthermore, from a policy perspective, these findings suggest that it might be possible to extend the variety of firms with which non-metropolitan universities collaborate by incentivising these universities to dedicate more resources to approaching regional firms. Policymakers should also consider measures such as increasing the funding available to incentivise research collaboration between SMEs and universities and promoting the involvement of SMEs in international value chains.

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Appendix 1 interview guides

Interview guide: Firm managers

Explanatory text for interviewees (company managers involved in innovation collaboration)

The purpose of this interview is to know how your firm got in contact with University XXXX [Stavanger, Aalborg, Aveiro], the reasons behind the start of this collaboration and how the collaboration unfolded over time. Previous research has observed that firms in sectors like yours are less likely to collaborate with universities compared to sectors like biotechnology. Such research has also suggested that the ways in which industry–university collaboration starts and unfolds might vary depending on whether firms are located in less densely populated regions or more densely populated regions.

Taking this research into account, I intend to compare this interview with interviews in firms in your sector or in sectors like yours, some of them in your region and others in other regions in Norway, Portugal and Denmark. The goal is to compare what leads firms to collaborate with universities and what leads this collaboration to unfold over time in regions without large metropolitan areas as well as regions with large metropolitan areas. With this goal in mind, the questions will focus on the following:

1. Characteristics of the company: main activities, product development, work organisation
2. How the current collaboration between the firm and the university began
3. Previous collaborations between the firm and the university or other universities; how they started

4. Collaboration with partners other than universities, like suppliers or customers; how they relate to the collaboration with the university

The answers that you kindly provide will be extremely useful in informing this research project and policies that can help firms like yours collaborate with universities and make the most of their collaboration with those universities. In return for your collaboration, we will send you a copy of the final project report. Thank you very much for your collaboration.

1. Interviewee position at the company

1.1. Could you describe your role at the company?

1.1.1. What is your background?

2. Information about the company

2.1. What are the main activities of the company?

2.1.1. Has the company changed the way it carries out its activities? →If yes, how so?

2.1.2. How does the company develop new products?

2.1.2.1. NOTE: The question can be shifted to "How does the company improve its production processes/ways of organising work responsibilities?" depending on the answer provided in 2.1.

3. Initiation and unfolding of industry–university collaboration

3.1. Now I would like to ask you about the company's collaboration with the university. What is the company doing with the university?

3.2. What are the goals of this collaboration?

3.2.1. How does the collaboration help the firm develop new products?

3.2.1.1. NOTE: The question can be shifted to "How does the collaboration help the firm improve its production processes/ways of organising work responsibilities and decision making?" depending on the goals formulated by the interviewee.

3.2.2. How did the collaboration start?

3.2.2.1. Possible probes depending on the interviewee's answer:

-When did the collaboration start?

-Who approached whom first – the company or the university?

-Who helped in connecting the firm with the university?→ How so?

-Were there any relations between the firm and the university before the collaboration started? → What kind of relations?

-What was happening at the company that might have facilitated the collaboration?

-Did driving time between the firm and the university play any role in the initiation of the collaboration? →What role did it play?

-Were there any challenges that posed an obstacle to further collaboration between your company and the university? → How did the company handle these challenges?

3.2.3. Is the collaboration between the firm and the university different now compared to when it started?

3.2.3.1. Probe depending on the interviewee's answer:

-In what ways is the collaboration different now compared to when it started?

-What has made the collaboration change?

-Has driving time between the firm and the university played any role in the evolution of the relationship since it started? →What role has it played?

3.2.4. Probe if this did not emerge in 3.2.2: "When was the first time the firm collaborated with a university?"

3.2.4.1. NOTE: If this is not the first time that the firm has collaborated with a university, the same question as 3.2.2. should be asked. Ultimately, the goal should be to probe until there is clarity on which processes led the firm to the first experience of industry–university collaboration. If the interviewee is not knowledgeable about earlier experiences of collaboration with universities, ask him/her to help me approach an interviewee at the company who can provide this information.

4. Role of other organisations in firms' engagement in industry–university collaboration

4.1. On a related note, does your company collaborate with organisations other than the university?

4.1.1. Probe if the answer is affirmative:

-What are these organisations? →Do these organisations include research and technology organisations other than universities?

-What are the goals of these collaborations? →How do they help the company develop new products/improve production processes/improve ways of organising work?

4.2. Have other organisations made collaboration with the university more likely?

4.2.1. Probe if the answer is affirmative:

-Which organisations have made collaboration with the university more likely? →How so? →Can you give examples of how they have contributed?

5. Future evolution of industry–university collaboration/closure questions

5.1. Do you expect the firm to engage in further collaboration projects with this university or other universities? →With what goals in mind?

Interview guide: University researchers

Explanatory text for interviewees (researchers involved in collaboration with the focal firm)

The purpose of this interview is to understand what made the firm that you are collaborating with interested in collaborating with University XXXX [Stavanger, Aalborg, Aveiro]. With this goal in mind, the insights from this interview will be combined with those from managers at the firm that you are collaborating with.

Furthermore, I aim to compare the insights from the interviews with you and the company managers with those from interviews with other university researchers and company managers, covering the experiences of industry–university collaboration in other regions of Norway, Portugal and Denmark. The goal of these comparisons is to obtain insights into what makes firms in regions that are less densely populated collaborate with universities, compared to firms in regions that are more densely populated. With this goal in mind, the questions will focus on the following aspects:

1. How the current collaboration between the firm and the university began
2. Previous collaborations between the firm and the university or other universities; how they started

The answers that you kindly provide will be extremely useful in informing this research project and policies supporting high-quality collaboration between universities and firms. In return for your collaboration, we will send you a copy of the final project report. Thank you very much for your collaboration.

1. Interviewee position at the university

1.1. Could you describe your role at the university?

1.1.1. What is your background?

2. Processes behind industry–university collaboration

2.1. Now I would like to ask you about your collaboration with company XX. What is the collaboration with company XX about?

2.2. What are the goals of this collaboration?

2.2.1. How does the collaboration help the firm develop new products?

2.2.1.1. NOTE: The question can be shifted to "How does the collaboration help the firm improve its production processes/ways of organising work responsibilities and decision making?"

2.2.2. How did the collaboration start?

2.2.2.1. Possible probes depending on the interviewee's answer:

-When did the collaboration start?

-Who approached whom first – the company or the university?

-Who helped in connecting the firm with the university?→ How so?

-Were there any relations between the firm and the university before the start of the collaboration? → What kind of relations?

-What was going on at the company that might have made the collaboration more likely?

-Were there any challenges that posed an obstacle to further collaboration between the company and the university? → How did the company handle these challenges?

2.2.3. Is the collaboration between the firm and the university different now compared to when it started?

2.2.3.1. Probe depending on the interviewee's answer:

-In what ways is the collaboration different now compared to when it started?

-What has made the collaboration change?

2.2.4. Probe if this did not emerge in 2.2.2: "Was this the first time the firm had collaborated with a university?"→If not, the same question as 2.2.2. should be asked. Ultimately, the goal should be to probe until it becomes clear which processes led the firm to the first experience of industry–university collaboration. If the interviewee is not knowledgeable about earlier experiences of collaboration with universities, I should ask him/her to help me approach another researcher who can provide this information.

3. Evolution of industry–university collaboration/closure questions

3.1. Do you expect the firm to engage in further collaboration projects with this university or other universities? →With what goals in mind?

Appendix 2 Supplementary tables

Table A1. NACE Rev. 2 sectoral codes excluded from the case selection (Source: Drejer and Østergaard, 2015, p. 15)

High-tech manufacturing codes
21: Manufacture of basic pharmaceutical products and pharmaceutical preparations
26: Manufacture of computer, electronic and optical products
Knowledge-intensive service codes
50: Water transport
51: Air transport
58: Publishing activities
59: Motion picture, video and television programme production, sound recording and music publishing activities
60: Programming and broadcasting activities
61: Telecommunications
62: Computer programming, consultancy and related activities
63: Information service activities
64: Financial service activities, except insurance and pension funding
65: Insurance, reinsurance and pension funding, except compulsory social security
66: Activities auxiliary to financial services and insurance activities
69: Legal and accounting activities
70: Activities of head offices, management consultancy activities
71: Architectural and engineering activities, technical testing and analysis
72: Scientific research and development
73: Advertising and market research
74: Other professional, scientific and technical activities
75: Veterinary activities
78: Employment activities
80: Security and investigation activities
84: Public administration and defence, compulsory social security
85: Education
86: Human health activities
87: Residential care activities
88: Social work activities without accommodation
90: Creative, arts and entertainment activities
91: Libraries, archives, museums and other cultural activities
92: Gambling and betting activities
93: Sports activities and amusement and recreation activities

Table A2.1 What initiated relations with the focal university, non-metropolitan cases

Case	How it started	
DK1 NM	**University consultant approached firm. University student internships**	Industrial PhD DK1 NM: "So, the [Aalborg University] consultant's job was to do some development, but not research collaborations as industrial PhD or another project. [...] It was [him/her] who approached the company. [...] We also had a couple of projects where there was a student worker."
DK2 NM	**Event organised at Aalborg University. Firm became acquainted with the interviewee, future CTO**	CTO DK2 NM: "That was back in 2007... during my master's thesis, where I had some collaboration with them. I met a guy from [firm where they are currently employed] at a presentation we both attended [at the university]. [...] They helped me build a wheelchair for some experimental studies at the university."
DK3 NM	**The firm approached the university through business networks**	Owner DK3 NM: "I have been in different networks. [...] And so they almost always said that there is this department at Aalborg University. [...] 15 years ago, a bit more, we began [...] That was in fact one student [...] that helped with the first materials we had in English and had some contact with England, and we had EU support funds."
PT1 NM	**Firm invited to event organised by Portuguese SME institute and Aveiro University**	CEO PT1 NM: "In 2009, I was at the first session on university–industry collaboration. This was promoted by the Portuguese SME Institute and the University of Aveiro, where we got to know the University of Aveiro and its technology transfer office." [Later on, the company approached the university for consultancy services and hosted student internships].
PT2 NM	**Researchers from the University of Aveiro approached the firm. Previous student contacts**	Researcher PT2 NM: "We contacted the enterprise [in 2008] to see if they were interested in going ahead with [...] development work on this new technology. That's true that they are working [...] with the conventional technology. [...] We had some previous contacts, as some of our students were doing their projects with them."
NO1 NM	**Firm approached University of Stavanger researcher because of customers' questions**	Researcher NO1 NM: "So, [former CTO] contacted me [in 2011] because they wanted to have some understanding of the [product] mechanics. And their customers came up with questions. [...] Then I just mentioned [to the company] [...] it is too late for a Bachelor project or master's project, but I have a semester project within a couple of months."
NO2 NM	**Firm approached University of Stavanger researcher because of customers' questions**	The firm approached the university in search of consultancy services. CEO NO2 NM: "A customer asked if we had a solution... if it's possible to do something with the [pipeline] pressure." / Managing director partner NO2 NM: "I didn't have the background from the multiphase flowing [needed for a client]. [...] I was googling multiphase flowing and [University of Stavanger researcher] came up."

Table A2.2 What initiated relations with the focal university, metropolitan cases

Case	How it started	
DK4 M	**Student internships, starting with the current CEO. Unclear who approached whom**	CEO DK4 M: "The first [intern] was in 1996, because that was when I started [laughs]. [...] I think the idea was that it is easier than if you want to hire an engineer; it is easier to have him for half a year because it is easier to see if he is good."
DK5 M	**Firm approached universities to create a reputation and attract candidates**	CEO DK5 M: "In 2007 or something, I said, 'I want the companies to say yes to every student who wants help [in a training position]'." / COO DK5 M: "We were also in a situation with this closeness, or whatever you want to call it, and our name not being known for what it stands for... when we had to do recruitment, we were competing a with Siemens, Carlsberg."
PT3 M	**Firm involved in third party–led research project application. Merged with another project application with focal university**	Head water department PT3 M: "The firm has been involved in [EU funded project] since 2013. [...] We were trying to start with another organisation, and on the other side there was the University of Évora and the institute. In Portugal, there were two projects pursuing the same idea, and we were told to join forces."
NO3 M	**Triggered by interviewee's presence at a sectoral conference. Third party encouraged the firm to approach the university**	Innovation manager NO3 M: "I was at a conference in March last year about fish farming. [...] One of the guys on that panel came from the Research Council of Norway… state organisation with lots of money… and said you should make a research program to find out all these other elements."

Table A3.1 Evolution of the relationship with the focal university, role of public funding, non-metropolitan cases

Case	Summary of changes	
DK1 NM	**Jump research partnership, supported by national public funding**	Industrial PhD DK1 NM: "So, I think one year before I started the PhD [2014], I think in the northern region, they had this meeting on research in the northern area […] In this meeting, the CEO attended and was definitely interested in the industrial PhD programme. [...] So, as I defended my PhD, I went into this postdoc position [supported by public technology demonstration programme]."
DK2 NM	**Jump research partnership, not supported by public funding**	CTO DK2 NM: "[Reasons for being hired as CTO in 2015] my profile was not just Aalborg University; it was also that my research was within the area of the company's products. [...] Er... public funding is difficult to get and takes a lot of time and it's not our focus."
DK3 NM	**Jump research partnership, supported by EU H2020 public funding**	CEO DK3 NM: "[Aalborg University researcher] has been work together with [owner DK3 NM]. […] [Aalborg University researcher] said, 'We have a project for you here. It's called [EU H2020 funded project]. It might be something for you'."
PT1 NM	**Jump research partnership, supported by EU H2020 public funding**	CEO PT1 NM: "I had a candidacy for an H2020 project which could be interesting for us to have something with a university on research and innovation, and that this innovation led to the publication of an article, no? [...] We went to the University of Aveiro [...] It was about doing structural calculations of the resistance of windmill lifts."
PT2 NM	**Jump research partnership, supported by EU H2020 public funding**	Innovation director PT2 NM: "I knew there were H2020 incentives to do small research projects. [...] They were projects of 15,000–20,000 euros that could be materialised in one year, and we started there in December 2016 with the team we have now."
NO1 NM	**Jump research partnership, supported by national public funding**	CTO NO1 NM: "So, I got the contact of [researcher NO1 NM] at the time I started, so I went to the university. [...] [In 2017] my boss came to me. I think [my boss] had a meeting at Innovation Norway and learned it was possible to do an industrial PhD."
NO2 NM	**Jump research partnership, not supported by public funding**	Managing director partner NO2 NM: "So, what we are doing now is to show it in a theoretical model as well, because actually what comes from UiS has credibility amongst all the operator companies [...] then we can get funding for running a full-scale test." /CEO NO2 NM: "If we had bigger frames in economics, I think that we would have run the project totally different way."

Table A3.2 Evolution of the relationship with focal university, role of public funding, metropolitan cases

Case	Summary of changes	
DK4 M	**Jump research partnership, supported by national public funding**	CEO DK4 M: "Then [2000], we had small projects, you can say, on the way, but mainly founded by the Danish government, where they wanted to make some connection between the university and the commercial partners."
DK5 M	**Jump research partnership, supported by national public funding**	The firm hosted a master's thesis student, who is currently an industrial postdoc, as part of its collaboration in NETWORK, an innovation network financed by Innovation Denmark. CEO DK5 M: "[NETWORK] contacted us because they thought that it might have relevance for us to be a part of it. Because we are probably known as very innovation heavy. And we are industry."
PT3 M	**Collaborative research project from the start, supported by EU non-H2020 public funding**	Head water department PT3 M: "In Portugal, there were three [EU non-H2020 fund programme] projects approved in 2013, and this was one of them."
NO3 M	**Collaborative research project from the start, supported by national public funding**	Innovation manager NO3 M: "So, we put together a group of companies [and universities] that actually each have different competence, you know, and we made an application and we got a budget and this programme will run for 3.5 years."

Table A4.1 Relevance of relationships with organisations other than universities, non-metropolitan cases

Case		
DK1 NM	**Attractiveness to international customers**	Industrial PhD DK1 NM: "New regulations mean that customers have problems with the engines. How can we cope with the problems? And can we be better than the competitors? So, in that sense, you can also say that the customers drive research. [...] So, the biggest companies are [foreign MNC competitors]. They are engine manufacturers. [...] How can we be better than our competitors? [...] And research is a big strategic factor there."
DK2 NM	**Attractiveness to customers, unclear if international**	CTO DK2 NM: "Most companies go towards mass products and cheap chairs. [...] Well, [DK2 NM] goes in the opposite direction: Make expensive chairs that are custom-made."
DK3 NM	**Attractiveness to local customers**	CEO DK3 NM: "Mainly we are in the Danish market. About 80% of our turnover is going to the Danish market. We're in Sweden, Germany and France... But it's mainly Denmark... [...] Our competitors… the largest of them also have a strength here [in the area of sustainability] but it is not at the same level as we are, to be honest."
PT1 NM	**Attractiveness to international customers**	CEO PT1 NM: "When we were about to curve this piece [of aluminium, for a German MNC supplier in the automotive industry], we did a test and we saw that curving that piece would be very complicated. [...] We contacted the University of Aveiro so that they could help us with the structural calculus to see how the piece would respond."
PT2 NM	**Attractiveness to international customers**	Innovation director PT2 NM: "[In energy efficiency] We started with Denmark, Norway, Sweden... [in 2009] they wanted to risk, and many are still with us. [...] We managed, in 2011, that our biggest client [...] shifted to energy efficiency. [...] [The current project with the University of Aveiro] has brought many ideas that are being applied to the products, and we have managed to reduce energy consumption a lot, which puts us at the level of the great European producers."
NO1 NM	**Attractiveness to international customers**	CTO NO1 NM: "From my boss' part, when they looked at it [the industrial PhD] for first time, I think they saw the opportunity to go in depth into the technical issues, because if we want to expand in the world, we need a stronger technical background. […] And that's also what we see when we go especially to Germany, maybe Holland too."
NO2 NM	**Attractiveness to international customers**	CEO NO2 NM: "It's a high cost when you go offshore and you test, so we need theoretical calculations and verifications that this is something doable." / Managing director NO2 NM: "So, what we are doing now is to show it in a theoretical model as well, because actually what comes from UiS has credibility amongst all the operator companies [...] then we can get funding for running a full-scale test."

Table A4.2 Relevance of relationships with organisations other than universities, metropolitan cases

Case		
DK4 M	**Attractiveness to international customers**	CEO DK4 M: "We are in a niche, you could say, but the pressure is getting bigger. And that's why we made that decision many years ago to turn up on R&D so we're sure we could compete. [...] And then… in order to be able to compete with the Asians, we need to have an R&D department. We need to be ahead. [...] You can say when we link with DTU, KU or whatever, is to be able to find technologies of proof of concept [...] that this will work."
DK5 M	**Attractiveness to international customers**	CEO DK5 M: "Primarily the big competitors are in Germany and Switzerland. And then there are some in Italy as well. [...] So, the reason many times that we are chosen as a supplier is because we can do the 20% [customised production] But we didn't have control over the 80% right. [...] Who can help us with that? And then we found out by coincidence actually that we had the NETWORK organisation." / COO DK5 M: "It was through [NETWORK], but it started as a master's thesis and then it was later on... was handed over to be a postdoc project, which we are doing now."
PT3 M	**Unknown**	Head water department PT3 M: "[PT3 M] is involved in [EU funded project] since 2013. [...] We were trying to start with another organisation [a civil society organisation], and on the other side there was the University of Évora and the institute. In Portugal, there were two projects pursuing the same idea, and we were told to join forces."
NO3 M	**Attractiveness to international customers**	Innovation manager NO3 M: "In Scandinavia, we are probably the biggest private-owned water treatment company. We have a factory in Sweden and a factory in Norway. We have our own distribution in Germany. We used to have it in Denmark. [...] But a very important factor is that when it comes to water production and water treatment, it has to do with competence [in different areas]."

Table A5.1 R&D among the non-metropolitan cases

Case	R&D department, initiation of collaboration with focal university	R&D department, currently	
DK1 NM	Yes	Yes	Industrial PhD DK1 NM: "What we did previously was okay: make a system, implement it in the engine, see how the engine reacts. […] Nowadays, we follow a more scientific path, where we do a model of how the lubrication affects the engine, how can we optimise that [...] Now they have separated the project and research departments, so projects are now focusing on delivering projects, and the research department is focusing on research."
DK2 NM	No	Yes	Press clipping DK2 NM: "With the 1st of September [2015], [DK2 NM] welcomes a new staff member. As R&D Manager, [CTO DK2 NM] is supposed to strengthen our development division regarding consistent further development of existing and new products. [...] [CTO DK2 NM] will introduce a rather scientific approach to good sitting postures. They will furthermore intensify [DK2 NM] cooperation with educational institutions."
DK3 NM	Unknown	Yes	Unknown.
PT1 NM	No	No	CEO PT1: "We do R&D inside [PT1 NM], probably the same or more than the university... but we don't call this R&D. It was about trying, correcting, trying again... okay? We don't call it R&D but it is."
PT2 NM	Yes	Yes	Innovation director PT2 NM: "We can go back to 2005 […] we started doing this research with the University of Coimbra. We were almost two years doing research, very focused on energy efficiency. […] After that, we became more interested in research."
NO1 NM	Unknown	Yes	CEO NO1 NM: "It was kind of a natural development in the scientific approach… We have several bachelors, masters… and it would be a natural development to go into the PhD to extend the knowledge."
NO2 NM	Unknown	Yes (formally. Role not salient at the practice)	CEO NO2 NM: "We have someone that is officially responsible for R&D, but it's typical Norwegian, and we are even more typical. It's done in the day-to-day organisation."

Table A5.2 R&D among the metropolitan cases

Case	R&D department, initiation of collaboration with focal university	R&D department, currently	
DK4 M	Yes	Yes	CEO DK4 M: "From the beginning, it was a bit different, and over the last 10 years, it has changed a lot. Maybe in the beginning, it was only 10% and today we are at least 30% [in R&D staff]. […] I would say we have a quite big engineering and research department. And we probably have 10 projects running at all times."
DK5 M	Yes	Yes	CEO DK5 M: "So, actually the research and the innovation and the collaboration between [the company and the university] originates from way back. [...] long history of patents on the technology and machinery."
PT3 M	Yes	Yes	Head water department PT3 M: "The relationships with universities grew [since 2011]; however, it was always more personal. All the years I teach at the university where I work [university other than the University of Évora]. [...] Personal relations always help in establishing contacts."
NO3 M	Yes	Yes	Innovation manager NO3 M: "Before we started [NO3 M], we had a master's student doing half a year of thesis work, doing the big research like you are doing now. [...] This is how we [started the company]... and this was done by University of Stavanger."

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